Atty. Docket No.155695-0221
Express Mail Label No.: EL922430987US

UNITED STATES PATENT APPLICATION

FOR

MICROWRIST SYSTEM FOR SURGICAL PROCEDURES

INVENTORS:

Dan Sanchez
Darrin Uecker
Oleg Svanidze
James Wright
Yulun Wang

PREPARED BY:

IRELL & MANELLA LLP
840 Newport Center Drive
Suite 400
Newport Beach, California 92660
(949) 760-0991

Atty Docket No. 155695-0221
Express Mail Label No. EL922430987US
464759

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a handle assembly for a medical robotic system.

2. Background Information

Historically, surgery has been performed by making large incisions in a patient to provide access to the surgical site. There has been developed instruments that allow a surgeon to perform a procedure through small incisions in the patient. The instruments include an endoscope which has a camera that allows the surgeon to view the internal organs of the patient through a small incision. Such procedures are less traumatic to the patient and have shorter recovery times than conventional surgical procedures. Endoscopic instruments have even been used to perform minimally invasive heart surgery. Blockage of a coronary artery may deprive the heart of blood and oxygen required to sustain life. The blockage may be removed with medication or by an angioplasty. For severe blockage, a coronary artery bypass graft (CABG) is performed to bypass the blocked area of the artery. CABG

procedures are typically performed by splitting the sternum and pulling open the chest cavity to provide access to the heart. An incision is made in the artery adjacent to the blocked area. The internal mammary artery is then severed and attached to the artery at the point of incision. The internal mammary artery bypasses the blocked area of the artery to again provide a full flow of blood to the heart. Splitting the sternum and opening the chest cavity can create a tremendous trauma to the patient. Additionally, the cracked sternum prolongs the recovery period of the patient.

Computer Motion of Goleta, California provides a system under the trademark ZEUS that allows a surgeon to perform a minimally invasive surgery, including CABG procedures. The procedure is performed with instruments that are inserted through small incisions in the patient's chest. The instruments are controlled by robotic arms. Movement of the robotic arms and actuation of instrument end effectors are controlled by the surgeon through a pair of handles and a foot pedal that are coupled to an electronic controller. Alternatively, the surgeon can control the movement of an

endoscope used to view the internal organs of the patient through voice commands.

The incisions create pivot points for the medical instruments. The pivot points constrain movement of the instruments within the patient to four degrees of freedom; translation, pan, tilt and rotation of the instrument shaft. Additionally, the pivot point may cause a reverse movement of the instrument. For example, leftward movement of the system input handle may actually cause a rightward movement of the instrument. The surgeon must compensate for such constraints, thereby increasing the difficulty of using the system for performing a medical procedure.

It would be desirable to provide a robotic handle that gives the user the sensation of controlling the tip of the instrument. It would also be desirable to generally improve the ergonomics of medical robotic master handles.

There have been developed medical robotic systems that create six degrees of freedom for the surgical instruments. Six degrees of freedom requires relatively complex mechanism that increases the size and cost of the system. It would be desirable to provide an effective medical

robotic system that would only require five degrees of freedom.

BRIEF SUMMARY OF THE INVENTION

A master robotic handle assembly that has only five degrees of freedom. The master handle assembly is used to move a robotically controlled surgical instrument.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a top view of an illustration of a robotic system;

Figure 2 is a perspective view of a surgeon control area of the robotic system;

Figure 3 is a perspective view of a handle assembly of the robotic system used to control a medical instrument;

Figure 4 is an enlarged perspective view of a wrist assembly of the robotic system controlled by a user's hand;

Figure 5 is a sectional perspective view of the handle/wrist assembly.

DETAILED DESCRIPTION

Disclosed is a medical robotic system with a handle assembly that is used to control a medical instrument. The handle assembly and medical instrument have five degrees of freedom. Five degrees of freedom may provide greater dexterity than medical robotic systems of the prior art with four or less degrees of freedom. Five degrees of freedom reduces the size and complexity of the instrument and the overall robotic system.

Referring to the drawings more particularly by reference numbers, Figure 1 shows a robotic system 10. The system 10 may include a plurality of robotic arms 12 located adjacent to a table 14. Two of the robotic arms 12 may control the movement of corresponding medical instruments (not shown). The third robotic arm 12 may control the movement of an endoscope (not shown). The robotically controlled instruments and endoscope may be used to perform a minimally invasive medical procedure on a patient lying on the table 14.

The robotic arms 12 and accompanying instruments may be the same or similar to robotic products sold by Computer

Motion under the trademarks AESOP and ZEUS. Although three robotic arms 12 are shown and described, it is to be understood that the system 10 may have a different number of arms 12.

The robotic arms 12 are controlled from a "surgeon" area 16. The surgeon area 16 may be located adjacent to the table 14. Alternatively, the surgeon area 16 may be coupled to the robotic arms 12 through a telecommunications link to allow a surgeon to have remote input into the system 10.

Figure 2 shows a surgeon area 16. The surgeon area 16 includes a pair of handle assemblies 18 located adjacent to a surgeon's chair 20. The handle assemblies 18 are coupled to a controller 22 that is also coupled to the robotic arms 12 and medical instruments. The controller 22 may include one or more microprocessors, memory devices, drivers, etc. that convert input information from the handle assemblies 18 into output control signals which move the robotic arms and/or actuate the medical instruments.

The surgeon's chair 20 and handle assemblies 18 may be in front of a video console 24. The video console 24 may

be linked to the endoscope to provide video images of the patient. The surgeon's area 16 may also include a computer screen 26 coupled to the controller 22. The screen 26 may display graphical user interfaces (GUIs) that allow the surgeon to control various functions and parameters of the system 10.

Each handle assembly 18 may include a handle/wrist assembly 30. The handle/wrist assembly 30 has a handle 32 that is coupled to a wrist 34. The wrist 34 is connected to a forearm linkage 36 that slides along a slide bar 38. The slide bar 38 is pivotally connected to an elbow joint 40. The elbow joint 40 is pivotally connected to a shoulder joint 42 that is attached to the controller 22.

Figure 3 shows a handle assembly 18 superimposed with a medical instrument 50. The instrument 50 includes an end effector 52 attached to an instrument shaft 54. The shaft 54 extends through a cannula 56 inserted through an incision of a patient 58. The incision defines a pivot point P for the medical instrument 50.

The shoulder joint 42 includes a sensor (not shown) that provides feedback on the movement of the handle about

a shoulder axis 60. The sensor may be a mechanical encoder, optical encoder, etc. or other device which provides an output signal that corresponds to a position of the handle 32 about the shoulder axis 60. The output of the shoulder sensor is provided to the controller 22. The controller 22 performs a series of computations to determine a corresponding movement of the medical instrument 50. The computations may include one or more transformation and kinematic equations. The controller 22 provides output signals to the corresponding robotic arm 12 to move the instrument 50 about point P as indicated by the arrow 62.

The elbow joint 40 includes a sensor (not shown) that provides positional feedback on the position of the assembly about an elbow axis 64. The controller 22 utilizes the positional feedback to drive the robotic arm and move the instrument in the direction indicated by the arrow 66.

The forearm linkage 36 and slide bar 38 create a translator 68 that allows linear movement of the linkage 36 along a translator axis 70. The translator axis 70

intersects with the axes 60 and 64. The translator 68 has a sensor (not shown) that provides feedback information that is used to drive the robotic arm and move the instrument 50 in the direction indicated by the arrows 72.

When transforming movement of the handle 32 to movement of the instrument 50 the controller 22 may equate the intersection of the axes 60, 64 and 70 to the instrument pivot point P. Equating the intersection of the axis 60, 64 and 70 with the pivot point P provides a kinematic relationship such that the surgeon "feel" like they are actually moving the instrument 50. Additionally, the length of the forearm linkage and location of the handle are such that the surgeon is provided with the sensation that they are holding and moving the distal end of the instrument. These relationships also improve the ergonomics of the handle assembly and the ease of use of the robotic system as a whole. The transformation and kinematic equations may be similar to the equations used in the AESOP and ZEUS products with the signs (+/-) reversed to account for the elbow axis 64 being behind the surgeon.

The handle assembly 18 has only five degrees of freedom; handle spin, wrist, translator, elbow and shoulder. Having only five degrees of freedom reduces the complexity of the system 10. The medical instrument 50 thus only needs a wrist with one degree of freedom which reduces the complexity, size and corresponding cost of the instrument. The configuation of the handle assembly allows the surgeon to perform any movement of the instrument with only five degrees of freedom.

Figures 4 and 5 show the wrist/handle assembly 30. The wrist 34 includes a joint shaft 74 that is coupled to the forearm linkage 36 by a roll bearing 76. The roll bearing 76 allows the handle 32 to rotate about a roll axis 78. The roll axis 32 may further include a sensor 80 that provide positional feedback to the controller 22. Movement of the handle 32 about the roll axis 78 may cause a corresponding rotation of the instrument end effector 52 in the direction indicated by the arrows 110 in Fig. 3.

The handle 32 includes a grasper 84 that is coupled to a handle housing 86. The housing 86 and grasper 84 are preferably shaped as an ellipsoid that allows the user to

more easily grasps the handle 32 with their hand. The housing 86 may have a thumb groove 88 that receives the user's thumb. The grasper 84 may have a pair of grooves 90 and 92 to receive the index and middle fingers of the user, respectively.

The handle 32 can rotate about a wrist axis 94. The wrist 32 provides a fifth degree of freedom not found in medical robotic systems of the prior art. The wrist 32 may include a sensor 104 that provides positional feedback for the controller 22. To improve the ergonomics of the wrist/handle assembly 30 the wrist axis 94 preferably intersects the roll axis 78 at a centroid 96 located between the thumb 98, index finger 100 and middle finger 102 of the user's hand. It has been found that such a configuration creates a more ergonomically correct feel of the handle 32 and movement of the handle assembly 30.

The sensors 104 provide positional feedback information to the controller 22 which is used to spin the medical instrument 50 as indicated by the arrows 82 in Fig. 3.

The grasper 84 can be depressed by user. The grasper 84 is coupled to a sensor 112 which provides feedback

information to the controller 22. The feedback information is used by the controller 22 to actuate the end effector 52 shown in Fig. 3. By way of example, depressing the grasper 84 may close the end effector 52. The grasper 84 may include a switch 114 that allows the user to lock the position of the grasper 84 and the end effector 52 of the corresponding medical instrument. The locking switch 114 may be coupled to a ratchet (not shown) that allows the grasper 84 and corresponding end effector 52 to be locked at a number of different positions.

The handle 32 may have a plurality of buttons 116, 118 and 120 that can be depressed by the user. By way of example, button 116 may be used to activate a cutting mode on a cauterizing end effector. Button 118 may be used to activate a coagulating medical instrument. The button 120 may be used to used to vary different functions of the system.

While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this

invention not be limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those ordinarily skilled in the art.